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OPTIMIZATION OF THE ADJUSTMENT PARAMETERS OF THE PERCUSSIVE DRILLING MACHINE

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Abstract: *The work presented consists in elaborating the methods of determining the parameters of the rational operating regime of the percussion drilling machine during its exploitation in the defined geological and mining conditions (Algerian career filafila)To define the purpose of empirical research, Is based on bibliographic research where several researchers have studied the method of drilling percussion with different methods based on the physico-mechanical properties of the rock, parameters of adjustment of the machine, geometrical parameters of the tool. The bibliographic analysis has shown that there are now certain methods of determining the dependencies of the drilling speed, and the penetration height is a function of the energy of a stroke of the piston and the drilling speed is A function of the height of penetration into the rock and the speed of rotation. The analysis of these methods shows that they are based on the knowledge of the peculiarities of the interaction of the tool against the rock. Each time, the parameters mentioned above are taken into account.*
Key words: *Rock, Percussive drilling, Energy of a stroke, Drilling process, Abrasiveness.*

1. INTRODUCTION

The mining industry is one of the largest branches of industry, includes the oil, gas, coal, mineral, metallic and non-metallic. The extension of the Algerian quarries has allowed the increase in productivity intended for export from 100 million dinars in 1966 to 900 million in 1986 Processed in Algeria for the national industry has 90%.

The complexity presented by the mining sector in the choice of a method rational exploitation adapted to the programmed and inspired objectives of the operating and profitability parameters. The choice of mechanization has a direct impact on production, prices and especially as investments are high. In terms of production the objective of our mines and quarries optimal exploitation of Algerian resources, taking into account their diverse technical, economic and human characteristics.

This gives some thought to the Work to be carried out and among them the drilling process which is the predominant factor In the development of a farm. By analyzing the geology of deposits of low, medium, and high hardness in the quarries of Algeria, we can deduce that the latter are of mountainous types.The Bridging inclination varies within the limits of 35° to 80°.the extraction work is done after drilling and firing.

The length of the front of the mining works is in general, within the limits of 200 to 700m with the benches having the width which varies from 8 to 15m.drilling is done using percussive drilling machines, it is known that the effective use of the drilling machines in question is related to the surrounding environment. The efficient use of drilling machines in Algerian quarries depends on the conditions of the research work: we tried to find the statistical parameters characterizing it by processing the data relating to each career Such a method makes it possible to replace all the existing quarries by only one, but having the same generalized characteristics and the prognoses corresponding to physico-mechanical properties of the rock. Many researchers have been trying to correlate the strength and various properties of mechanical rock Protodyakonov [1] described the Rock Resistance Coefficient (CRS) test used as a measure of the impact resistance of rock. The CRS test was then modified by Paone et al. [2], Tandanand and Unger [3] obtained simple relations between CRS and compressive strength, Rabia and Brook [4] used the modified test apparatus to determine the impact hardness number of the rock and developed an empirical equation to predict drilling speeds for DTH and drifting drills. Singh [5] showed that the compressive strength was not directly related to the drilling speed of a drill Clark [6] stated that the strength of drilling depends mainly on the hardness and the triaxial strength of the rock. Pathinkar and Misra [7] concluded that the properties of the rock such as compressive strength, tensile strength, specific energy, Shore hardness, Mohs hardness do not, individually, make it possible to establish good correlation with penetration rate of impact drilling. Hengyu Songand and Huaizhong Shi studied the effectiveness of energy transfer from percussive drilling[8].

Percussive drilling is widely used in the mining industry and the construction of holes in the rock. Usually the drilling of the rock, containing an alternate hammer drill, is placed hole, The mode of percussive drilling is widespread during the exploitation of ore deposits [9]

Some researchers have experimentally or percussively investigated impact drilling, which they have conducted in laboratory experiments to determine the exploitation indices and the technical characteristics. Sementchenko A. [10] studied the operating regime of mining machines, R. Poderni [11] has calculated the setting parameters of mining machines, the choice of mining machines [12], [13], [14].

2. THE OPERATING PRINCIPLE OF THE PNEUMATIC PERFORATOR MARTAU

Hammers or perforators are intended for the drilling of mine holes in very hard, hard and medium formations. They are often used in underground mines, open-cast mining and construction. The use of pneumatic drills is widespread in mine work because of the advantages they offer, such as: simplicity of construction compared to other types, high efficiency and safety during operation. The pneumatic drill is a percussion machine consisting of a cylinder, a ratchet wheel, a compressed air distribution device, a piston, a bushing, a helical rod and a a mandrel.

The purpose of the rotation mechanism is to rotate the drilling tool at a certain angle (6-15°) for the successive destruction of the size of the borehole over its entire surface. Depending on the stroke of the piston, there is the rotating mechanism depending. The dependent rotating mechanism rotates the tool during the return path of the piston. It is represented either by a helical rod or a piston with a shank provided with a helical thread.

In the first case (Fig. 1), the ratchet ring 1 is fixed to the cylinder 2, it is provided with several orifices to allow the penetration of the compressed air into the distribution box 10.

Inside the ratchet ring, is installed the head of the helical rod 3 with the pawls 9. The pawls are pressed by springs introduced into the vanes 7 and are in permanent contact with the teeth of the ring 1.

The rotation of the helical rod whose filtering with a big step, is only possible in one direction; that is to say during the race of work.

The rod through the nut 4 enters the piston 5 connects to the rotating sleeve 6 by grooves. During the working stroke, the pawls do not prevent the rod from rotating, which is why the piston moves without rotation and longitudinal grooves of the piston are associated with the sleeve. During the idle stroke the helical rod is blocked by the pawls, which causes the piston to slide into the grooves of the helical rod and rotate at a certain angle. The rotation of the piston obligatorily causes the rotation of the sleeve as well as that of the foil 11.

The mechanism with helical rod, (Fig. 1) has great reliability. The angle of rotation of the drill bit can be easily varied by changing the nut and the helical rod.

The operation of drilling machines and particularly hard is realized under the influence of external conditions that vary in a random way. The adjustment of the drilling machine is carried out by the variation of the parameters of the working regime.

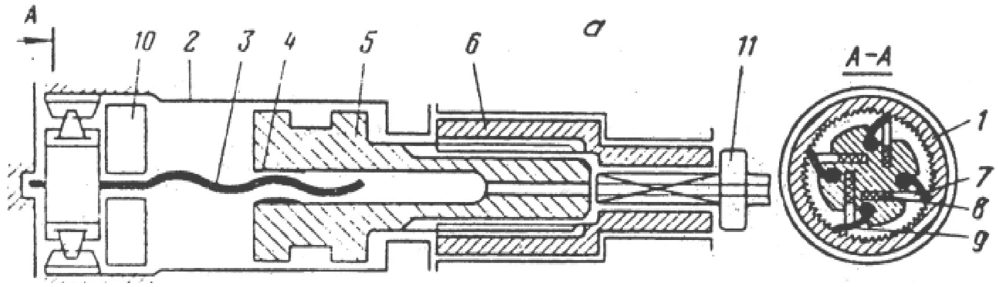

Fig. 1. Mechanism of rotation [15].

This is why it is necessary to know the dependencies between these parameters and external factors. In addition, the parameters of the work patterns of the drilling machine must be coordinated with the factors characterizing the firing work [16].

The choice of perforators, the main issue that concerns us has always been the productivity that can ensure the perforator in well-defined conditions, but this factor remains related to the operating speed of the machine, which in turn depends on the properties of the rock , the type of the tool and the parameters of the perforator without neglecting the factors that may have an influence on the choice of the operating regime, such as: the maximum power, the maximum forward speed that the perforator can provide, the penetration height of the tool during the destruction of the rock according to the tool parameters and the torque. [17].

3. ANALYSIS OF THE PHYSICO-MECHANICAL PROPERTIES OF ROCKS INFLUENCING THE DRILLING PROCESS

3.1 Idnex of abrasiven

An method is proposed for the determination of the resistance to the impression P_k, this method consists in depressing the stamp in the form of a trunk of cane on the surface of the raw rock (untreated); the use of this index as a criterion of the efficiency of the drilling process has allowed to receive the values of the coefficients of variation which do not exceed zero, this index is more preferable compared to the coefficient of hardness, but there exist cases or the coefficient of variation remains considerable, one of the causes is that this index does not take into account the capacities of the rock to use the working tool; to correct this inconvenience, Baron and Kouznotsov [18], have proposed the method of applying this ability called abrasiveness.

The results of the researches carried out show that the common account of the indices solidity and abrasiveness allows to receive the parameters of drilling with the coefficient of variation not exceeding 10%, so it is recommended to receive the most certain data to appreciate the rocks of after two characteristics, impression resistance and abrasiveness; abrasiveness must be taken into account if its value exceeds 10 mg, if it is necessary to obtain the rapid information on the mechanical properties of the rocks, it is possible to take into account or use the coefficient of hardness

The tests of the rocks on the abrasivity were carried out according to the methodology proposed by Baron L. and Koznotsov. The essence of this is to rub a steel rod on the surface of the rock sample, and to determine the loss of weight during the experiment, so the abrasiveness criterion is a summary loss the weight of the rod (in mg) during 10 minutes of friction between the rod and the rock with which the friction of the rod is done with the force of 15kgf and the speed of rotation 400 rpm. The test piece of rock (1) is tested by means of a stand (Fig. 2) and the packing (3) of a device (2) is clamped to the horizontal top facet. During the test, a measuring rod (4) fixed in a mandrel (5) of a machine to be drilled and lowered on the sample and the motor (7) of the machine tool is started. The requested axial force is provided by the load (6).The measuring rod is made of unhardened steel. Before the test the stem is weighed using the analytical balance with the accuracy of 0.1 mg. After having tested for 10 minutes, the rod is moved so that it is turned from the other end to the rock; then we connect the machine for 10 mn.

The abrasiveness index is calculated by the following formula

$$a = \sum (P_{1i} - P_{2i}) / 2N \qquad (1)$$

Where; N: The number of tests in each sample.

P_{1i}: Initial sample weight.

P_{2i}: Final sample weight

After the tests carried out, the following results were obtained:

Sample of the ore: am = 4mg.

Sample of sterile: as = 5mg.

The results obtained are compared with the recommendations of the classification proposed by Baron. L [19]. We can say that the limestones of the Filafila quarry refer to the first class that is to say of a very weak abrasiveness.

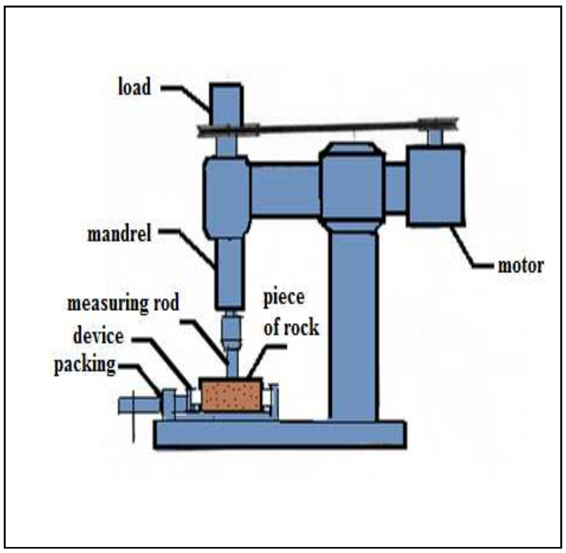

Fig. 2. Stand for determining the abrasiveness of rocks.

3.2 Index impression resistance

The determination of the index of resistance to the imprint was carried out by means of a mechanical press the press in question consists of a base or one installs all the necessary equipment of two slide along which a Plunger (3) on the upper table thereof a sample (4) which is fed by a fixed stamper (5) into a clamping device (6), the die (Fig. 3) is made of steel Soaked; During the tests, the load on the stamp is increased until a punch is formed in the sample.; during the tests, the load on the stamp is increased until the formation of a pouch in the sample.

The index of the impression resistance is calculated by the following formula:

$$p_k = \sum F_i / N \cdot S \qquad (2)$$

Where: Fi: Charge when a poquet is formed.

S: Area of the cross section of the stamp.

N: The number of tests in each sample.

The rocks studied have an average footprint resistance of 105 Kgf / mm². These rocks relate to the class called "average hardness".

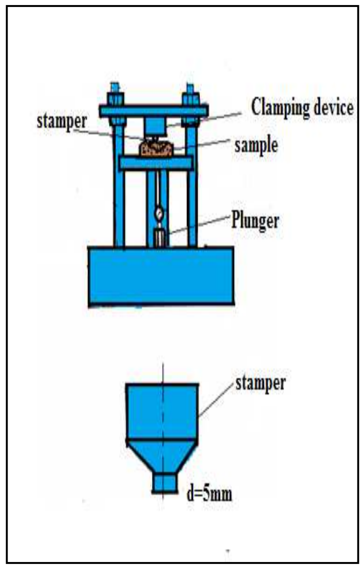

Fig. 3. Stand for the determination of strength indexes, impression resistance and compressive strength [20].

4. THE GEOMETRICAL PARAMETERS OF THE PERFORATOR

The geometrical parameters of the perforator are indicated on Figure 4.

The useful surface area of the piston to carry out the way outward journey in (m²) is :

$$S_a = \frac{\pi}{4}\left(D^2 - d_2^2\right) \qquad (3)$$

And for the way return:

$$S_r = \frac{\pi}{4}\left(D^2 - d_1^2\right) \qquad (4)$$

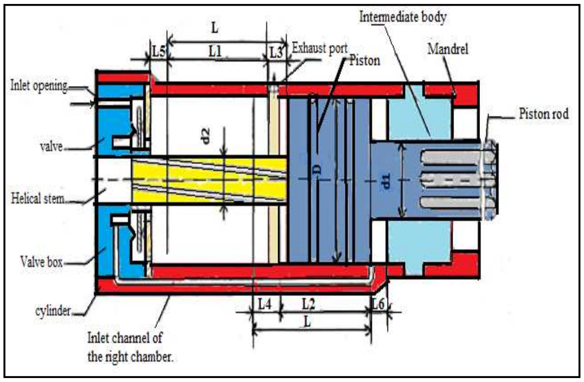

Fig 4: Diagram of determination of basic parameters of perforators

Where; D -diameter of the piston, m

d_1 -diameter of the stem of the piston, m

d_2 -diameter of the helical rod, m

The force applied to the piston during the way outward journey in (kgf) is equal to:

$$F_a = (S_a \cdot p_a - S_r \cdot p_e) \cdot k_1 \qquad (5)$$

And during the way return:

$$F_r = (S_r \cdot p_a - S_a \cdot p_e) \cdot k_2 \qquad (6)$$

Where: P_a-pressure of compressed air in the cylinder intake chamber. It is equal to the pressure in the power grid, Pa;

P_e -air pressure in the exhaust chamber, Pa

P_e 0.08 to 0.12 MPa;

K_1 - coefficient taking into account friction losses between the piston and the cylinder,

K_1:0.85 to 0.95;

K_2 - coefficient taking into account losses by friction and rotation of the foil,

K_2: 0.5 to 0.7.

To simplify the determination speeds we admit that the movement of the piston to the opening of the exhaust port (under the action of the force F_a is uniformly accelerated. This is why the maximum speed of the piston at the distance l_1 in (m/s) is determined by:

$$V_a = \sqrt{\frac{2F_a \cdot l_1 \cdot g}{G}} \qquad (7)$$

And that, at the distance l_2 during the way return:

$$V_r = \sqrt{\frac{2F_r \cdot l_2 \cdot g}{G}} \qquad (8)$$

Where;

G - piston weight, N;

g - acceleration of gravity, g = 9.61 m/S²

. The number of strokes of the piston per minute is beats per minute:

$$n_c = \frac{60}{T_c} \qquad (9)$$

With; $$T_c = t_a + t_r \qquad (10)$$

The duration of the outward journey will be:

$$t_a = \frac{G \cdot V_a}{g \cdot F_a} + \frac{L - l_1}{V_a} \qquad (11)$$

And that of the return journey:

$$t_r = \frac{G \cdot V_r}{g \cdot F_r} + \frac{L - l_2}{V_r} \qquad (12)$$

the number of revolutions of the foil by minute in(tr/mn):

$$n_t = \frac{L}{h} \cdot n_c \qquad (13)$$

Where h is the step of the threading of the helical rod, h = 0.8 to 1.0 m.

The number of blows of the piston by a turn by a foil in (blows /tr) is equal to:

$$n_c' = \frac{n_c}{n_t} \qquad (14)$$

One can determine the swing angle of the foil by a blow in (degree) according to the expression:

$$\varphi = \frac{360^0}{n_c'} \qquad (15)$$

5. METHODOLOGY OF WORK

The operating productivity (Q_{exp}) is a function of the mechanical drilling speed (V_f) and consequently the supply pressure (Pa) the problem posed consists in determining the values of the adjustment parameters or the minimum cost price of one meter of the drilled hole.

- Determination of the drilling speed:

$$\sigma_d = 300\,(5 + f - \sqrt{25 + 10.f}\ ) \qquad (16)$$

f: The hardness of the rock; f =7

$$Vf = \frac{1{,}3.E_{ou} \cdot n_c}{d_f^2 \cdot \sigma_d} . \tau_e \qquad (17)$$

E_{ou}: The energy of a shot of the piston;
nc: Number of piston strokes;
The yield of the energy transmission from foil to rock is taken from τ_e = 0.4 to 0.7;
df: Drilling diameter (44 mm)

- The theoretical productivity:

$$Q_{theo} = 60 \cdot V_f \qquad (18)$$

- Technical productivity:

$$Q_{tech} = \frac{T - T_{pr}}{\left(\frac{1}{V_f} + t_{aux}\right) \cdot K_{rep}} \qquad (19)$$

- Operating productivity:

$$Q_{exp} = Q_{theo} \cdot K_{exp} .T \qquad (20)$$

Where: t_{aux} Duration of auxiliary operations reduced to one metre of drilled hole, (min/m);
T_{pr} : Duration of preparatory operations, (min);
T: Workstation time, (min);
K_{rep} : Coefficient taking into account the workers' break.
K_{exp} : operating coefficient

The cost structure of one meter of the drilled hole consists of two parts: Time-dependent expenses related to the productivity of the drilling works as well as to the measurement of a tool. It should be said that the cost price of One meter of the drilled hole is the criterion that takes into account the technical level of machinery used and the organization of work. If it concerns the exploitation of the machines of the chosen drillings allowing to drill holes of determined diameter. The most accurate criterion for determining the parameters of the rational drilling regime will be the cost price of one meter of drilled hole. The latter can be determined according to the following formula (DA/m):

$$C = \left(\frac{C_p}{Q_{exp}}\right) + \left(\frac{C_{ou}}{H}\right) \qquad (21)$$

C_p : Expense relating to the operation of the rotary hammer by post.
Q_{exp} : Operating productivity per punch positioner.
C_{ou}: Neck: Tool price.
H: Metering of the drilled holes relating to a tool; (m).

6. RESULTS AND DISCUSSION

The results of the tests carried out in the rock (marble) are presented in the tables:

Table 1

Determination of compressive strength and strength (S=48cm²)

Variety of marble	Testing	Force applied; kgf	Impression resistance; kgf/mm²	Average value
Ore	01 02 03	1520 1510 1515	53,79 53,43 53,61	53,68
Sterile	01 02 03 04 05 06 07 08	1040 1010 990 1020 1050 1040 1020 1040	3680 35,74 35,03 36,09 37,15 36,80 36,09 36,80	36,23

Table 2

Determination of impression resistance; Kgf/ mm²
(S=28.26 cm²)

Variety of marble	Testing	Force applied; kgf	Solidity	Abrasiveness (mg)	Compressive strength (kgf / cm2)
Ore	01	33000	6, 90	0.004	690
	02	37200	7,75	0.005	775
	03	46128	9,61	0.004	961
Sterile	01	25000	5.20,83	0.005	520, 83
	02	10200	2.12,58	0.005	212,58
	03	40760	0,4916	0.005	49,16
	04	35100	7,3125	0.005	731,25
	05	31500	6,5625	0.005	656,25
	06	35750	7,4479	0.005	744,79
	07	12600	6,2650	0.005	626,50
	08	15000	3,1250	0.005	312,50

The results obtained for determining the operating parameters of a hammer drill are shown in Table 3

Table 3

Basic parameters of the pneumatic drill

P_a Kgf/cm²	F_a kgf	F_r Kgf	V_1 m/s	V_2 m/s	t_a s	t_r s	T_c s	n_c c/mn	n_t tr/mn	n'_c tr/mn	φ (°)	E_c Kgf.m
2	22.58	5.72	2.61	1,26	0.023	0.049	0.072	833.33	41.88	27.03	13.31	0.60
2,5	33.26	10.87	3.17	1.74	0.020	0.035	0.055	1090.9	41.11	27.03	13.31	0.89
3	43.93	17.83	3.65	2.23	0.016	0.027	0.043	1395.3	51.62	27.03	13.31	1.18
3,5	54.61	23.89	4.07	2.59	0.015	0.023	0.038	1578.9	58.42	27.03	13.31	1.47
4	65.29	29.95	4.45	2.90	0.014	0.021	0.035	1714.2	63.42	27.03	13.31	1.76
4,5	75.97	36.01	4.80	3.18	0.013	0.018	0.031	1935.4	71.61	27.03	13.31	2.05
5	86.65	42.01	5.13	3.43	0.011	0.017	0.028	2142.8	79.28	27.03	13.31	2.33
5,5	97.33	48.12	5,43	3.67	0.011	0.016	0.027	2222.2	82.22	27.03	13.31	2.62
6	108.0	54.18	5,72	3.90	0.011	0,015	0.026	2307.6	85.38	27.03	13.31	2.91
6,5	118.6	60.24	6	4.11	0.010	0,014	0.024	2500	92.5	27.03	13.31	3.20

Table 4 shows the results of calculation the productivity of the hammer perforator.

Figures (5) and (6) show the results obtained respectively from the variations of the energy of a piston stroke and the drilling speed as a function of the compressed air pressure, the productivity as a function of the drilling speed.

Table 4

Productivity of the hammer drill

Pa kgf/cm²	V_f m /mn	H m	Q_{the} m/p	Q_{tech} m/p	Q_{exp} m /p
2	0,036	600	17,28	17,21	17,01
2,5	0,07	530	33,6	33,39	32,99
3	0,11	500	52,8	52,27	51,84
3,5	0,16	470	76,8	76,33	73,42
4	0,21	420	100,8	98,48	94,34
4,5	0,28	380	134,4	129,96	122,16
5	**0,36**	**360**	**172,8**	**165,19**	**157,07**
5,5	0,41	350	196,8	186,76	169,83
6	0,48	300	230,4	216,57	193,30
6,5	0,57	220	273,6	253,62	221,61

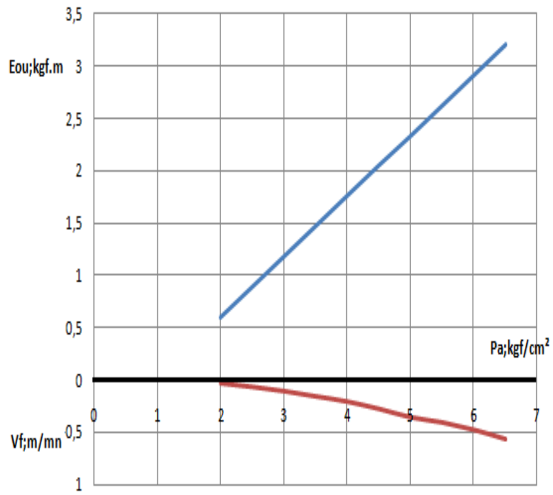

Fig. 5. The variation of the energy of a stroke of the piston and the drilling speed as a function of compressed air pressure

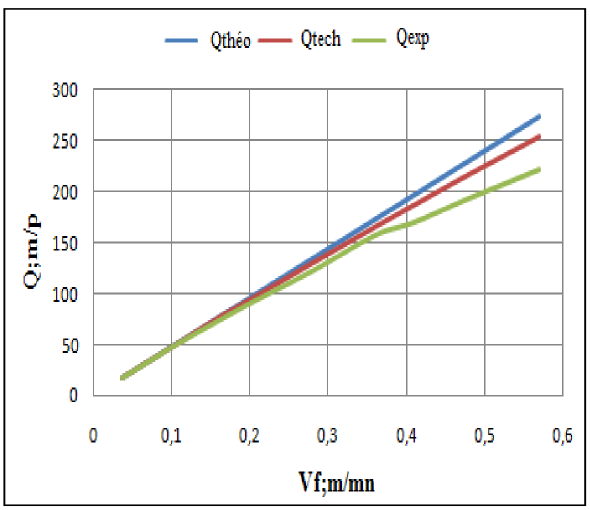

Fig. 6. The variation of the productivity according to the speed of drilling

It is noted that the energy of a blow of the pneumatic drill piston and the drilling speed increases so that the pressure of compressed air increases so the relationship is proportional (Fig.5). On our side the productivity of the pneumatic perforator increases as the drilling speed increases to improve the organization of work. The productivity of the pneumatic perforator depends primarily on the parameters of the drilling regime because these determine the value of the drilling speed (Fig. 6). The study of the curves presented leads to a recommendation on the improvement of work organization, which gives us the possibility of increasing the operating productivity of the pneumatic drill and reducing the cost price of the machine.

The rational parameters of the operating regime of percussive drilling machines under the conditions of the marble quarry (Filfila) cited above are shown in the following table:

Table 5

Optimal parameters of the hammer drill.

Pa Kgf/Cm²	**Ec** kgf. m	**Vf** m/mn	**Productivity**		
			$Q_{thé}$ m/p	**Q_{tech}** m/p	**Q_{exp}** m/p
5	2,33	0,36	172,8	165,19	157,07

The calculation results in question are qualitative and can be considered as approximate, therefore it is necessary to extend the research in question by studying the drilling process given its complexity. These have highlighted the following information, by varying the settings of the machine, we can determine or the technical productivities, operating and the cost depending on the drilling speed and the drilled footage. The index to limit the setting parameters of the machine is a technical-economic index. This last check exactly the rationality of the operating regime of the drilling machine.

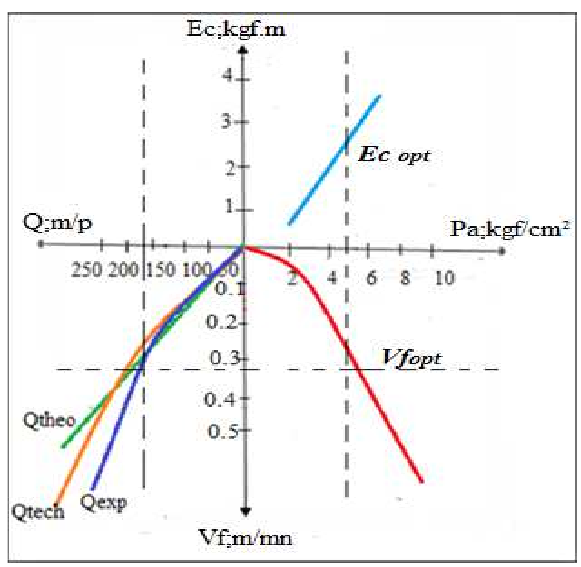

Fig. 7. Nomogram for determining the optimal values of the operating speed of percussive drilling machines

7. CONCLUSION

In our work we have studied the percussive drilling mode with different methods based on the physico-mechanical properties of the rock, machine control parameters, geometric parameters of the tool. We studied the influence of the borehole footage on drilling speed. Knowing that the setting parameters have a significant influence on the output parameters. The factors studied represent the values of the variables in the field at which the study of the drilling process begins with the aim of obtaining the optimal values of these factors. The factors studied (compressed air pressure, piston stroke) represent variables. , that is to say during the experimental drilling, we can give them certain values.

As a result of research carried out, we concluded that under quarry conditions employing the defined drilling means, it is preferable to use the 1 meter drilled hole cost criterion to determine the parameters of the rational operating regimes.

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Optimizarea parametrilor de reglare a mașinii de găurit cu percuție

Rezumat: lucrarea prezentată constă în elaborarea metodelor de determinare a parametrilor regimului de operare rațional al mașinii de găurit cu percuție în timpul exploatării sale în condițiile geologice și miniere definite (fila de carieră algeriană) Pentru a defini scopul cercetării empirice, se bazează pe cercetare bibliografică în cazul în care mai mulți cercetători au studiat metoda de foraj percuție cu diferite metode bazate pe proprietățile fizico-mecanice ale rock, parametrii de ajustare a aparatul, parametrii geometrici ai mașinii. Analiza bibliografică a arătat că există acum anumite metode de determinare a dependențelor vitezei de foraj, iar înălțimea de penetrare este o funcție a energiei unui accident vascular cerebral al pistonului și viteza de foraj este o funcție a înălțimii penetrarea în stâncă și viteza de rotație. Analiza acestor metode arată că acestea se bazează pe cunoașterea particularităților interacțiunii instrumentului împotriva stâncii. De fiecare dată, parametrii menționați mai sus sunt luați în considerare.

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